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Original Research Article

Bumblebee Habitats as a Part of Sustainable Ecotourism: Analysis from Regional Distribution in Arunachal Himalaya, India

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Abstract: Bumblebees are one of the natural resources in the region that attracts nature lovers for their beautiful colour patterns as well as for their pollination behaviour. Therefore, to study the possibility of including bumblebees as a part of sustainable ecotourism, quantitative assessment of the bumblebees in Arunachal Pradesh was conducted. We monitored 5-10 transects of 25 × 1 m inside each of 31 grid cells of ~ 6.3 × 6.3 km planned. The study recorded 13 species of bumblebees with the highest species richness in the western part of the state. The top three grid cells for bumblebee diversity in terms of Shannon and Simpson indices are located in alpine meadows. All of these locations are adjacent to tourist areas. This indicates the potential for western Arunachal Pradesh to include bumblebees for ecotourism. In addition, 19 species of forage plants of bumblebees belonging to 12 families were recorded from the region. Principal component analysis loading score shows that the density of bumblebees is positively associated with altitude > humidity > sunlight intensity and negatively associated with ambient temperature.

Keywords: Arunachal Pradesh, Bombus, Bumblebee, Ecotourism, Environmental factors, Forage plant, Species richness

Introduction

The geographic location of Arunachal Pradesh, the state with rich biodiversity, rich cultural heritage of 26 major tribes have contributed to draw increasing attention and inflow of tourists into the region. In 2005, tourist arrivals in the state reached 50,873 with 50,560 domestic visitors and 313 foreign visitors. The number increased to 5,20,089 (5,12,436 domestic and 7,653 foreign tourists) in 2018 (Pandey *et al*., 2006; Cyriac *et al*., 2019). The noticeable growth indicates that tourism can be a major path for sustainable socio-economic development for the region if it is promoted with proper planning and management because it is reported that an increase in tourism significantly enhances gross domestic product (GDP), foreign direct investment, energy development, agriculture development and reduces poverty in the long run (Khan *et al*., 2020).

Bumblebees are a group of long-tongued, large-sized bees with long hair. The bright colour patterns of body hair have long attracted nature lovers. They are also well known as pollinators of crops, fruits and wild plants (Tayeng and Gogoi, 2016; Wahengbam *et al*., 2019). Diversity in colour patterns is further increased by the colour variation within many species (Williams, 2007). The name bumble or humble originated from their buzzing or humming, describing the low resonant sound they generate while vibrating the wing muscles. This insect group belongs to the genus *Bombus* of the order Hymenoptera. The name *Bombus* is derived from

the Greek imitative word that means to hum or boom (Sladen, 1912; Buchmann, 1985).

They are native inhabitants of the northern continents of Europe, Asia, and North America, especially in mountainous regions. In the Himalayas, they are encountered at altitudes ranging from 300 m to over 5,000 m above mean sea level. India is home to 67 of the 2288 known species of bumblebees, although they are absent from the plains of India (Williams, 2004; Williams, 2022). In tropical regions, they are generally confined to the mountains. In Africa, they are reported only from the north coast. Likewise, no native species are found to occur in Australia and New Zealand. Seven species are reported from Brazil (Williams, 2007; Françoso, de Oliveira and Arias, 2015).

Observing the importance of the tourism industry in the Himalayan region and the attraction of nature lovers to bumblebees, the present work aims to study the geographic distribution and richness of bumblebee species in Arunachal Pradesh, to analyse the prospects for including bumblebees as a component in ecotourism.

Materials and methods

Arunachal Pradesh was divided into three zones viz. eastern, central, and western and the grid cells for the survey were chosen accordingly. Grid cells of ~ 6.3 × 6.3 km were planned by the Ashoka Trust for Research in Ecology and the Environment (ATREE), India for long-term monitoring of the biodiversity and habitat parameters of the northeastern region of India and these were used in this study. Inside each of these grid cells, 5-10 transects of 25 × 1 m were monitored for sampling purposes (Pollard, 1977). For each, the investigator walked at a speed of ~ 0.3 km h^{-1} to cover each transect for estimating the abundance of the bumblebees. A total of 31 grid cells were monitored during the period from April 01, 2018, to March 31, 2020.

Geo-coordinates were located using GPS (Garmin Oregon 750). Sunlight intensity (Lux) was recorded using a digital lux metre. Temperature and humidity were recorded using Kestrel 5700 Elite data logger. All processed specimens are being curated in the Laboratory of Entomology, Zoology, Rajiv Gandhi University, Arunachal Pradesh. Species were identified based on DNA barcode (partial mtCOI sequence) and morphological characters (Williams *et al*., 2010). Diversity indices and principal component analysis (PCA) were computed using the software PAST (Hammer, *et al*., 2001).

Results

Diversity of bumblebees

A total of 13 species of bumblebees were recorded during the present study. They belong to five subgenera: *Pyrobombus* (5 species), *Melanobombus* (4 species), *Alpigenobombus* (2 species), *Psithyrus* (1 species), *Orientalibombus* (1 species). Abundance of the bumblebees was recorded in the order: *Bombus* (*Pyrobombus*) *lemniscatus* >*B.* (*Pyrobombus*) *mirus* >*B.* (*Pyrobombus*) *luteipes* >*B.* (*Melanobombus*) *prshewalskyi* >*B.* (*Melanobombus*) *miniatus* >*B.* (*Orientalibombus*) *haemorrhoidalis* >*B.* (*Pyrobombus*) *pressus* >*B.* (*Alpigenobombus*) *breviceps* >*B.* (*Pyrobombus*) *abnormis* >*B.* (*Psithyrus*) *novus* >*B.* (*Melanobombus*) *festivus* >*B.* (*Alpigenobombus*) *sikkimi* >*B.* (*Melanobombus*) *eximius* (Fig. 1). These were recorded from 24 grid cells. Grid cells in western Arunachal showed higher species richness, followed by the central and eastern zone (Table 1). Simpson and Shannon diversity indices showed very similar patterns. Grid cell 78M/14SW3 (Jang) showed maximum richness with a record of seven species: *B. lemniscatus*, *B. miniatus*, *B. luteipes*,

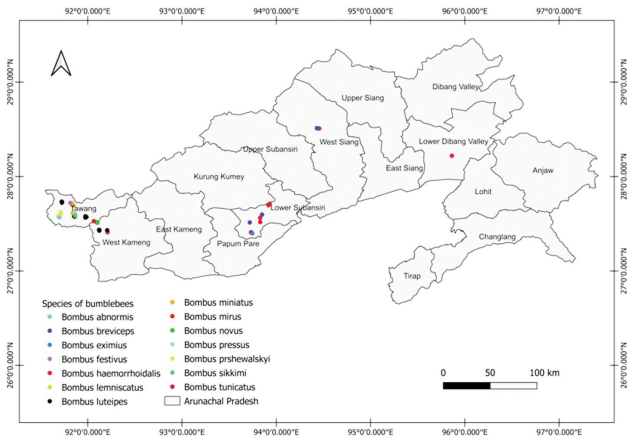

Fig. 1. Map of Arunachal Pradesh showing distribution of bumblebee species.

B. pressus, *B. abnormis*, *B. sikkimi* and *B. mirus* (Fig. 2). Grid cell 78M/14NW3 (Shangestar) showed the second highest richness with six species: *B. mirus*, *B. miniatus*, *B. prshewalskyi*, *B. pressus*, *B. abnormis* and *B. festivus* (Fig. 2). Grid cell 83A/2SW4 (Sela Pass) showed third position in species richness with four species: *B. lemniscatus*, *B. mirus*, *B. prshewalskyi* and *B. novus* (Fig. 2). All of these grid cells with alpine meadows are located in the western zone of Arunachal Pradesh (Table 2). These grid cells are located at an altitude of 2692–4231 m asl. In these grid cells, the ambient temperature varied from 11–25.5°C, relative humidity from 59–85%, and sunlight intensity from 4300–76900 lux during the period of the survey (Table 3). The grid cell 83E/11NE4 (Takampassa, Yaizat) ranked fourth in terms of species richness with three species viz. *B. breviceps*, *B. haemorrhoidalis* and *B. eximius*. It is located in Lower Subansiri district with a sub-tropical vegetation pattern (Table 2). The altitude of this grid cell ranged from 565–789 m asl. The ambient temperature in this grid was 24–28.8 °C, relative humidity 71–82 %, and sunlight intensity 310–8600 lux (Table 3).

Factors influencing bumblebee diversity

Principal component analysis (PCA) scatter plot shows that different parts of Arunachal Pradesh are highly variable in terms of bumblebee diversity, altitude, and humidity (Fig. 3). It presented five derived variables. Out of these, only the first principal component shows an eigenvalue above one (2.68, 64.16%) (Fig. 4). For the first principal component (PC 1), the altitude, bumblebee density, sunlight intensity and humidity show positive values in the loading plot, while the ambient temperature loading is negative. Thus, from the PCA loading score, the density of bumblebees is positively associated with altitude > humidity > sunlight intensity and negatively associated with ambient temperature (Fig. 5).

Forage resources

During the present study, a total of 19 plant species belonging to 12 families is recorded as forage resource of bumblebees (Table 4). These include six species belonging to the family

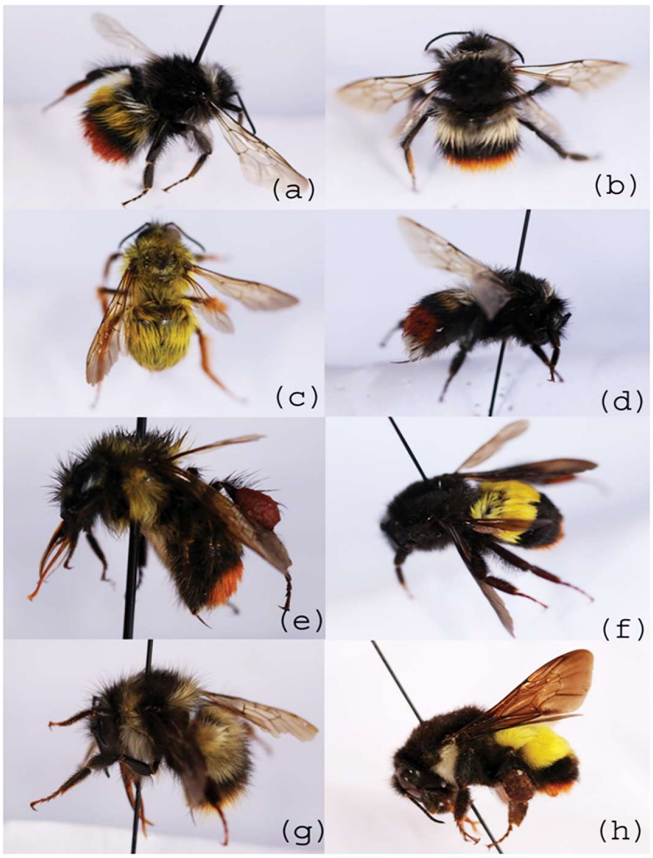

Fig. 2(a-h). (a) *Bombus lemniscatus*, (b) *B. mirus*, (c) *B. luteipes*, (d) *B. prshewalskyi*, (e) *B. miniatus*, (f) *B. haemorrhoidalis*, (g) *B. pressus, (h) B. breviceps*

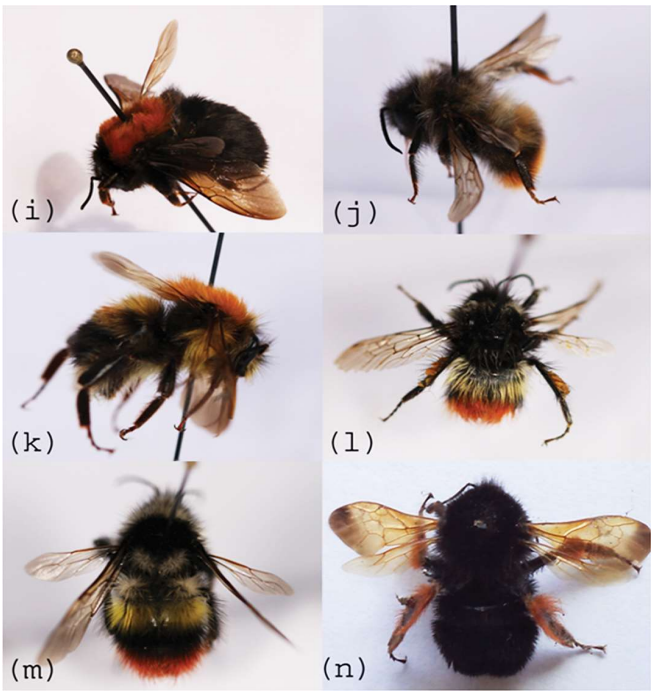

Fig. 2 (i-n). (i) *B. abnormis*, (j) *B. novus*, (k) *B. festivus*, (l) *B. sikkimi*, (m) *B. sikkimi*, (n) *B. eximius*.

Asteraceae, two species each of Balsaminaceae and Caprifoliaceae, and one species from each of Melastomataceae, Malvaceae, Lamiaceae, Cucurbitaceae, Actinidiaceae, Brassicaceae, Rosaceae, Amaranthaceae, and Polygonaceae. The *Pogostemon elsholtzioides* and *Raphanus sativus* were recorded during winter. All other forage resources were recorded during the summer season.

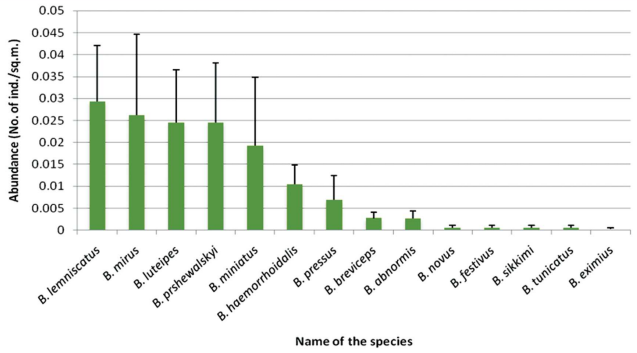

Fig. 3. Abundance of bumblebees in Arunachal Pradesh.

Discussion

The 13 species of bumblebees recorded during the present survey in Arunachal Pradesh represent ~ 4.51 % of the 288 species of bumblebee species known worldwide (Williams, 2022). In this study, the highest species richness was recorded in grid cells located at altitude 2692–4231 m asl. These grid cells, located in Sela Pass-Tawang tourist circuit, are the habitats for 10 species of bumblebees*B. lemniscatus*, *B. mirus, B. luteipes, B. prshewalskyi, B. miniatus*, *B. pressus*, *B. abnormis*, *B. festivus, B. sikkimi* and *B. novus*. These species are mainly inhabitants of subalpine and alpine regions at the highest elevations (Williams *et al*., 2010). Low altitude grid cell 83E/11NE4, located in Lower Subansiri district, with altitude 565 to 789 m asl and subtropical vegetation pattern, showed richness next to the mentioned high altitude grid cells in Tawang and West Kameng district. The species *B. breviceps*, *B. haemorrhoidalis* and *B. eximius* were mainly found in low altitude regions. During this survey, 76.92 % of the bee species were recorded in the high elevation zone of Tawang and West Kameng district and 23.07% species were found in the low altitude region of Lower Subansiri district. In these regions,

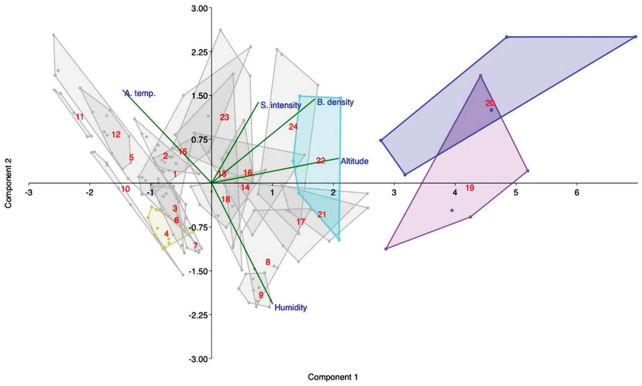

Fig. 4. Principal component analysis (PCA) scatter plot showing variation of survey grid cells relative to bumblebee density, ambient temperature, relative humidity, sunlight intensity and altitude.

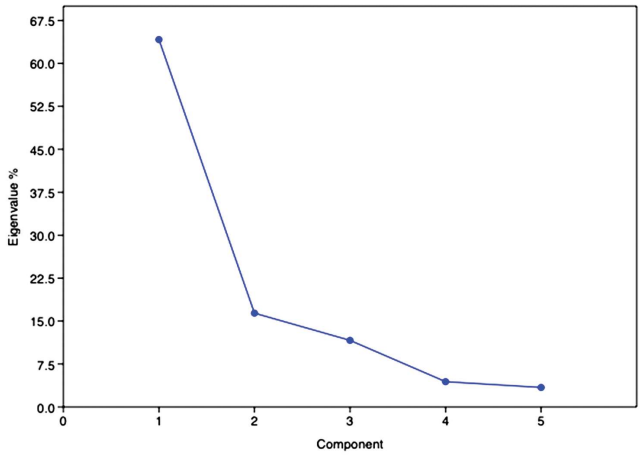

Fig. 5. Eigen value (%) of derived components in PCA.

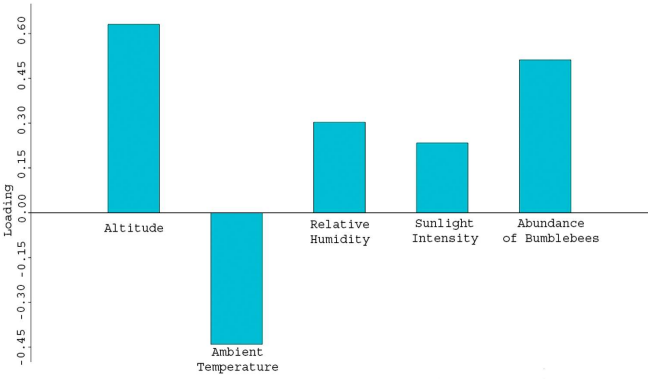

Fig. 6. Scores of bumblebee abundance, ambient temperature, relative humidity, sunlight intensity, and altitude in PCA loading plot.

the ambient temperature was recorded as 11-25.5°C and 24-28.8°C. The preference for lower temperatures was also evident from the PCA loading plot and agrees with the idea that bumblebees are primarily inhabitants of cool and alpine

Table 1. Diversity of bumblebees in different grid cells in Arunachal Pradesh.

Sl.No. in PCA plot	Grid cell no.	No. of species	Simpson (1-D)	Shannon (H)	Dominance (D)	Evenness (eH/S)
1	83E/14 SW3	2	0.412	0.602	0.588	0.913
2	83E/15NW3	1	0.000	0.000	1.000	1.000
3	83E/10 SE4	1	0.000	0.000	1.000	1.000
4	83E/11NE4	3	0.571	0.956	0.429	0.867
5	83E/14 NE4	1	0.000	0.000	1.000	1.000
8	82P/16 NW3	1	0.000	0.000	1.000	1.000
15	82L/7NE3	2	0.253	0.420	0.747	0.761
17	83A/3NW4	1	0.000	0.000	1.000	1.000
18	83A/3NE4	2	0.444	0.637	0.556	0.945
19	83A/2SW4	4	0.678	1.169	0.322	0.804
20	78M/14NW3	6	0.737	1.453	0.263	0.713
21	78M/14SE3	2	0.496	0.689	0.504	0.996
22	78M/14SW3	7	0.774	1.655	0.226	0.748
23	78M/10SE3	3	0.480	0.803	0.520	0.744
24	78M/10NE3	2	0.499	0.692	0.501	0.999

Table 2. The land use and land cover (LULC) pattern in the surveyed grid cells with bumblebees.

Sl. No. in PCA plot	Grid cell no.	Location	LULC
1	83E/14 SW3	L. Subansiri	Bamboo forest, pine forest, agricultural landscape
2	83E/15NW3	L. Subansiri	Fishery, pine forest, shrub land and grassland
3	83E/10 SE4	L. Subansiri	Sub-tropical forest
4	83E/11NE4	L. Subansiri	Sub-tropical forest
5	83E/14 NE4	Kamle	Human settlement
8	82P/16 NW3	L. Dibang Valley	Temperate forest
15	82L/7NE3	Mechuka	Temperate forest
17	83A/3NW4	Dirang	Pine forest
18	83A/3NE4	Dirang	Pine forest
19	83A/2SW4	West Kameng	Moist alpine meadow
20	78M/14NW3	Tawang	Alpine meadow, alpine forest
21	78M/14SE3	Tawang	Alpine forest
22	78M/14SW3	Tawang	Alpine meadow
23	78M/10SE3	Tawang	Alpine forest
24	78M/10NE3	Tawang	Alpine forest

regions. The preference for cool climates may be linked to their origin and dispersal estimated at the Eocene-Oligocene transition, which was a period of dramatic global cooling (Williams *et al*., 2022).

In this study, the highest species richness of bumblebees was recorded from alpine meadows. Nine species of wild forage plants were recorded from these meadows. Besides providing forage resources, these habitats may provide better nesting sites for bumblebees that nest underground in abandoned rodent nests, or on the surface in a ball of dried grass, or around human habitation, under rocks or in tree cavities (Alford, 1975; Williams, 1991; Hatfield *et al*., 2012). In addition, bumblebees were found to forage from certain crops and fruits in the region. Other studies have reported some agricultural habitats, such as hay meadows and pastures as suitable to bumblebees (Carvell, 2002; McFrederick and LeBuhn, 2006; Goulson, 2010; Rao and Stephen, 2010). Some species were also reported even from urban gardens and parks (McFrederick and LeBuhn 2006; Matteson *et al*., 2008). They are also found to forage from crops such as red clover

Table 3. Range of elevation and environmental parameters in the grid cells surveyed with bumblebees.

Sl. No. in PCA plot	Grid cell no.	Altitude range (m asl)	Temperature range (°C)	Relative humidity range (%)	Sunlight intensity range (lux)
1	83E/14 SW3	1519-1698	27.6-27.8	49-74	10-12830
2	83E/15NW3	1411-1639	25-31.7	45-78	260-14440
3	83E/10 SE4	1118-1614	23-28.8	60-81	500-7840
4	83E/11NE4	565-789	24-28.8	71-82	310-8600
5	83E/14 NE4	716-1071	25.1-39.9	36-82	1020-15220
8	82P/16 NW3	1539-2338	15.7-19	59-88	1890-13730
15	82L/7NE3	1145-1166	26.8-31	68-78	2000-53500
17	83A/3NW4	2114-3318	19.5-24.1	69.5-89.7	5000-28500
18	83A/3NE4	1688-1817	22.4-26.5	66.7-80.2	4400-90000
19	83A/2SW4	3848-4231	11-16	69-84.7	4300-76900
20	78M/14NW3	3657-4266	12.1-19.6	59.9-75	6000-65300
21	78M/14SE3	2234-3030	17-22.5	75.5-81.5	3500-60500
22	78M/14SW3	2692-3475	17.6-25.5	59-85	6900-66000
23	78M/10SE3	1597-2227	24.5-32	50.8-74.8	2000-60300
24	78M/10NE3	2137-2543	20-29	57-86	14000-82400

Table 4. List of forage resources of bumblebees recorded.

Sl. No.	Forage plant		Family	Name of the bumblebee species	Season
	Vernacular name	Scientific name			
1.	Beggar ticks	*Bidens pilosa*	Asteraceae	*B. luteipes*	Summer
2.	Common thistle	*Cirsium verutum*	Asteraceae	*B. haemorrhoidalis*	Summer
3.	Falconer's thistle	*Cirsium falconeri*	Asteraceae	*B. breviceps*	Summer
4.	Siam weed	*Chromolaena odorata*	Asteraceae	*B. haemorrhoidalis*	Summer
5.	Dandelion	*Taraxacum officinale*	Asteraceae	*B. prshewalskyi*	Summer
6.	Snow lotus	*Saussurea* sp.	Asteraceae	*B. prshewalskyi*	Summer
7.	Himalayan melstome	*Melastomamalabathricum subsp. Normale*	Melastomataceae	*B. breviceps*	Summer
8.	Cuban jute	*Sidar hombifolia* (=*S. rhomboidea*)	Malvaceae	*B. breviceps*	Summer
9.	East Himalayan Balsam	*Impatiens arguta*	Balsaminaceae	*B. breviceps*	Summer
10.	Shangri-La Balsam	*Impatiens chungtienesis*	Balsaminaceae	*B. mirus*	Summer
11.	Pogostemon	*Pogostemon elsholtzioides*	Lamiaceae	*B. breviceps*	Winter
12.	Cucumber	*Cucumis sativus*	Cucurbitaceae	*B. luteipes*	Summer
13.	Kiwi	*Actinidia deliciosa*	Actinidiaceae	*B. breviceps*	Summer
14.	Radish	*Raphanus sativus*	Brassicaceae	*B. haemorrhoidalis*	Winter
15.	Hibiscus	*Hibiscus* sp.	Rosaceae	*B. breviceps*	Summer
16.	Crocus stuff	*Achyranthes aspera*	Amaranthaceae	*B. luteipes*	Summer
17.	Himalayan Teasel	*Dipsacus asper* (=*Dipsacus inermis*)	Caprifoliaceae	*B. luteipes*	Summer
18.	Pincushion flower	*Pterocephalus hookeri*	Caprifoliaceae	*B. pressus*	Summer
19.	Rose carpet knotweed	*Bistorta vaccinifolia*	Polygonaceae	*B. prshewalskyi, B. miniatus*	Summer

(*Trifolium pratense* L.), field bean (*Vicia faba* L.), alfalfa (*Medicago sativa* L.) radish (*Raphanus sativus*) and fruits such as kiwi (*Actinidia deliciosa*) (Free, 1970; Tayeng and Gogoi, 2016).

More than 70 species of plants in 54 genera belonging to 30 families have been reported in previous studies from the Himalayan region (Table 5) (Williams, 1991; Sinu *et al.*, 2011; Abrol and Shankar, 2013; Tayeng and Gogoi 2016; Raina *et al.*, 2017; Raina *et al.*, 2019; Streinzer *et al.*, 2019, Thakur*et al.*, 2020). Out of these reported forage species, the family Asteraceae comprises the most with 12 species, like the findings of the present study, where it represents 31.57% of species.

Fig. 7(a-h). Bumblebees foraging on (a) *Bidens pilosa,* (b) *Cirsium verutum,* (c) *Cirsium falconeri,* (d) *Chromolaena odorata*, (e) *Taraxacum officinale,* (f) *Saussurea* sp., (g) *Melastoma malabathricum,* (h) *Sidar hombifolia*

Fig. 7(i-n). Bumblebees foraging on (i) *Impatiens arguta,* (j) *Impatiens chungtienesis,* (k)*Pogostemon elsholtzioides,* (l) *Cucumis sativus,* (m) *Actinidia deliciosa,* (n) *Hibiscus* sp

Fig. 7(o-r). Bumblebees foraging on (o)*Achyranthes aspera*, (p)*Dipsacus asper,* (q)*Pterocephalus hookeri,* (r)*Bistorta vaccinifolia*

The family Lamiaceae followed the Asteraceae with six species of forage plants. Among the bumblebees recorded, *B. novus* is a social parasite, i.e. it exploits the colonies of other bumblebee species for raising its brood (Lhomme and Hines, 2018).

A few bumblebee species are used commercially for the pollination of greenhouse crops. The mass rearing of bumblebee colonies for commercial purposes started in the mid-1980s and since then has expanded into a worldwide industry to worth crop value up to millions of euros (Velthuisand van Doorn, 2006, Williams *et al.*, 2008). Most of the species used for commercial captive rearing belong to two subgenera, *Bombus* (sensu stricto) and *Pyrobombus* (Velthuisand van Doorn, 2006; Williams *et al.*, 2008). These are all pollen-storing species, which store pollen in wax cylinders near to the brood clumps, as opposed to the pocket-making species, which pack the pollen into pockets next to the developing larvae, which feed directly. Workers of pollen-storing species feed larvae with a regurgitated mixture of pollen and honey. Pollen-storing species can be fed additional pollen, which aids in their domestication (Owen, 2016).

The highest species richness of bumblebees in Arunachal Pradesh was found near Sangestar lake and in the Jang of Tawang district and Sela Pass of the West Kameng district. Tawang district is bordered by Tibet (China) to the north and Bhutan to the southwest. The Sela ranges separate

Table 5. Forage resources of bumblebees reported from Himalayan region.

Sl. No.	Plant Family	Name of the plant species
1.	Acanthaceae	(i) *Adhatoda vasica*, (ii) *Pteracanthus urticifolius*
2.	Actinidiaceae	(i) *Actinidia deliciosa*
3.	Amaryllidaceae	(i) *Allium* sp.
4.	Araliaceae	(i) *Hedera nepalensis*
5.	Asteraceae	(i) *Artemisia absinthium*, (ii) *Carduus nutans*, (iii) *Cirsium falconeri*, (iv) *Cirsium wallichii*, (v) *Cynara scolymus*, (vi) *Dahlia variabilis*, (vii) *Dalhia verbalis*, (viii) *Echinops niveus*, (ix) *Helianthus annuus*, (x) *Saussurea* sp., (xi) *Tagetes patula*, (xii) *Zinia elegans*
6.	Balsaminaceae	(i) *Impatiens glandulifera*, (ii) *Impatiens sulcata*, (iii) *Impatiens balsamina*, (iv) *Impatiens scabrida*
7.	Bignoniaceae	(i) *Incarvillea* sp.
8.	Boraginaceae	(i) *Myosotis sylvatica*
9.	Brassicaceae	(i) *Brassica campestris*, (ii) *Brassica juncea*, (iii) *Raphanus sativus*
10.	Caprifoliaceae	(i) *Dipsacus inermis*
11.	Convolvulaceae	(i) *Convolvulus arvensis*, (ii) *Convolvulus* sp.
12.	Cucurbitaceae	(i) *Cucurbita pepo*
13.	Ericaceae	(i) *Rhododendron* sp.
14.	Fabaceae	(i) *Indigofera* sp., (ii) *Lotus corniculatus*, (iii) *Lupinus polyphyllus*, (iv) *Trifolium pretense*, (v) *Trifolium rapense*
15.	Gentianaceae	(i) *Swertia* sp.
16.	Hypericaceae	(i) *Hypericum oblongifolium*
17.	Lamiaceae	(i) *Marrubium vulgare*, (ii) *Nepeta* sp., (iii) *Prunella vulgaris*, (iv) *Salvia* sp., (v) *Scutellaria linearis*, (vi) *Stachys sericea*
18.	Lythraceae	(i) *Punica granatum*
19.	Malvaceae	(i) *Althaea rosea*, (ii) *Lavatera cashmeriana*, (iii) *Malva neglecta*
20.	Myrtaceae	(i) *Callistemene linearis*
21.	Orobanchaceae	(i) *Pedicularis pectinata*
22.	Papaveraceae	(i) *Papaver rhoeas*
23.	Plantaginaceae	(i) *Antirrhinum majus*, (ii) *Digitalis lanata*, (iii) *Digitalis purpurea*
24.	Primulaceae	(i) *Primula* sp.
25.	Ranunculaceae	(i) *Delphinium ajacis*
26.	Rosaceae	(i) *Cotoneaster* sp., (ii) *Cydonia oblonga*
27.	Rutaceae	(i) *Citrus aurantianus*
28.	Scrophulariaceae	(i) *Buddleja paniculata*
29.	Solanaceae	(i) *Lycopersicon esculentum*, (ii) *Solanum nigrum*
30.	Verbenaceae	(i) *Duranta plumieri*

West Kameng district to the East. Elevations of the Sela-Tawang tourist circuit range between 1818–6666m with a cool temperate climate. The area is both historically and naturally of special interest. Tawang Monastery is the largest monastery in India and the second largest in the world after the Potala Palace in Lhasa, Tibet. In addition, there are many beautiful glacial lakes in and around Tawang with crystal blue waters, such as Sela lake, Pangateng Tso (lake), Sangestar lake, and Banggachang lake. These remain frozen in winter, while in summer they become a haven for migratory birds. All these elements attract tourists from other parts of the country and from abroad every year, making it a good tourist destination. The area also has many waterfalls including Jang falls (Nurongneng waterfall) (https://www.arunachaltourism.com/). In addition to these, the Tawang district provides a habitat for ~488 species of birds (Lepage, 2020). Some of the more important bird sites in the Sela-Tawang tourist circuit are Zemithang, Tawang, Lumla and Sela Pass. High altitude birds like Blood Pheasant, Snow Partridge, Grandala, and Rose finches are some of the major attractions for bird watchers in the region. The Zemithang valley of Tawang district is one of the wintering sites of the vulnerable Black-necked crane,

migrating probably from Tibet. This bird also spends the winter in Sangti valley and Chug valley of the neighbouring West Kameng district (Chandan *et al*., 2014; Mize *et al*., 2018). The Eaglenest wildlife sanctuary is another birding destination. Around 650 species of birds are reported from this sanctuary. The sanctuary has become a prime destination for bird watchers from all around the world for Bugun Liochicla, which was discovered in 2006 and is endemic in the region (Athreya, 2006; Rahmani *et al*., 2016).

Likewise, Yaizat and Takampassa are villages in the Yazali area of the Lower Subansiri district, which exhibited fourth position in known bumblebee diversity within the state. These are located at distances of 20 and 45 km away from the tourist destination Ziro, the headquarter of the district. Ziro is a beautiful plateau and one of the oldest towns in Arunachal Pradesh. This beautiful hill station is located 1500 m above sea level. The place has an imposing landscape of beautiful lush green forest, rivulets, and a rich diversity of orchids. It is famous for paddy-cum-pisciculture. The area is renowned for its terraced paddy fields where the local people practice the unique system of poly-culture and water management. Further, the Talley valley wildlife sanctuary located at a distance of 35 km from the headquarters Ziro is another focus for ecotourism (https://www.arunachaltourism.com/). Around 409 species of birds are known from the sanctuary (Das, 2019). These include the near-threatened magnificent Ward's Trogon. It is limited to the eastern Himalayas in India, with a disjunct population in Fan-Si-Pan in northern Vietnam. Besides, the other specialty of this area is the Red Crossbill, the Vulnerable Rufous necked Hornbill, Kaleej Pheasant, Black Eagle, birds such as Minlas, Yuhinas, Niltavas, Tesias, Crossbills, Grosbeaks, Buntings, Bullfinches etc. (Krishna *et al*., 2015).

Thus, of the popularity of these areas, uniqueness, accessibility, and distance from major tourist spots, the bumblebees and their habitats could become an important part of the tourist attraction. In addition, all the other resources in Tawang and Lower Subansiri district and their adjoining areas as discussed attract tourists from different parts of the country and abroad every year making a good tourist destination. These tourists including birdwatchers could also enjoy the bumblebees especially when the weather is less favourable for bird watching.

Conclusion

The rich biodiversity of bumblebees in and around the tourist destinations of Sela-Tawang tourist circuit and Ziro shows the potential for including bumblebees as a component of ecotourism in the region. The diversity of bumblebees in the region could be further enriched by suitable conservation and management measures for maintaining flower-rich sites, species-rich grasslands, and promoting wildlife-friendly gardening and organic agriculture practices. Thus, bumblebees may be used to promote the local tourism sector as well as the agriculture and horticulture industry through pollination activity. In addition, the management of native bumblebees in the region through recreational activities will help to conserve their populations at a time when declining populations are being reported from many parts of the world.

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